CAMPBELL SCIENTIFIC
WHEN MEASUREMENTS MATTER

USER MANUAL

LWS Dielectric Leaf Wetness Sensor

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CSL 771

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PLEASE READ FIRST

About this manual

Please note that this manual was originally produced by Campbell Scientific Inc. primarily for the North American market. Some spellings, weights and measures may reflect this origin.

Some useful conversion factors:

Area: 1 in^2 (square inch) = 645 mm^2

Length: 1 in. (inch) = 25.4 mm
1 ft (foot) = 304.8 mm
1 yard = 0.914 m
1 mile = 1.609 km

Mass: 1 oz. (ounce) = 28.35 g
1 lb (pound weight) = 0.454 kg

Pressure: 1 psi (lb/in^2) = 68.95 mb

Volume: 1 UK pint = 568.3 ml
1 UK gallon = 4.546 litres
1 US gallon = 3.785 litres

In addition, while most of the information in the manual is correct for all countries, certain information is specific to the North American market and so may not be applicable to European users.

Differences include the U.S standard external power supply details where some information (for example the AC transformer input voltage) will not be applicable for British/European use. *Please note, however, that when a power supply adapter is ordered it will be suitable for use in your country.*

Reference to some radio transmitters, digital cell phones and aerials may also not be applicable according to your locality.

Some brackets, shields and enclosure options, including wiring, are not sold as standard items in the European market; in some cases alternatives are offered. Details of the alternatives will be covered in separate manuals.

Part numbers prefixed with a "#" symbol are special order parts for use with non-EU variants or for special installations. Please quote the full part number with the # when ordering.

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Campbell Scientific Ltd can advise on the recycling of the equipment and in some cases arrange collection and the correct disposal of it, although charges may apply for some items or territories.

For further advice or support, please contact Campbell Scientific Ltd, or your local agent.

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Precautions

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND **TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC**. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.eu or by telephoning +44(0) 1509 828 888 (UK). You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, or 20 feet, or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.

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LWS Dielectric Leaf Wetness Sensor

1. Introduction

Direct measurement of leaf wetness is problematic. Secure long-term attachment of a sensor to a representative living leaf is difficult. Leaf position, sun exposure, and health are in constant flux. To avoid these problems, leaf wetness sensors have been developed to estimate by inference the wetness of nearby leaves. The LWS estimates leaf surface wetness by measuring the dielectric constant of the sensor's upper surface. The sensor is able to detect the presence of miniscule amounts of water or ice. Individual sensor calibration is not normally necessary.

NOTE This manual provides information only for CRBasic dataloggers. It is also compatible with most of our retired Edlog dataloggers. For Edlog datalogger support, see an older manual at *www.campbellsci.com/old-manuals* or contact a Campbell Scientific application engineer for assistance.

2. Cautionary Statements

- READ AND UNDERSTAND the *Precautions* section at the front of this manual.
- Care should be taken when opening the shipping package to not damage or cut the cable jacket. If damage to the cable is suspected, consult with a Campbell Scientific application engineer.
- Although the LWS is rugged, it should be handled as a precision scientific instrument.
- Over time, the accumulation of dust and bird droppings can cause the dry output to rise. We recommend that the sensor be periodically cleaned using a moist cloth, or when you detect elevated dry output.
- The LWS is intended only for applications wherein the datalogger provides short excitation, leaving the probe quiescent most of the time. Continuous excitation may cause the probe to exceed government specified limits on electromagnetic emissions.

3. Initial Inspection

- Upon receipt of the LWS, inspect the packaging and contents for damage. File damage claims with the shipping company.
- The model number and cable length are printed on a label at the connection end of the cable. Check this information against the shipping documents to ensure the correct product and cable length are received.

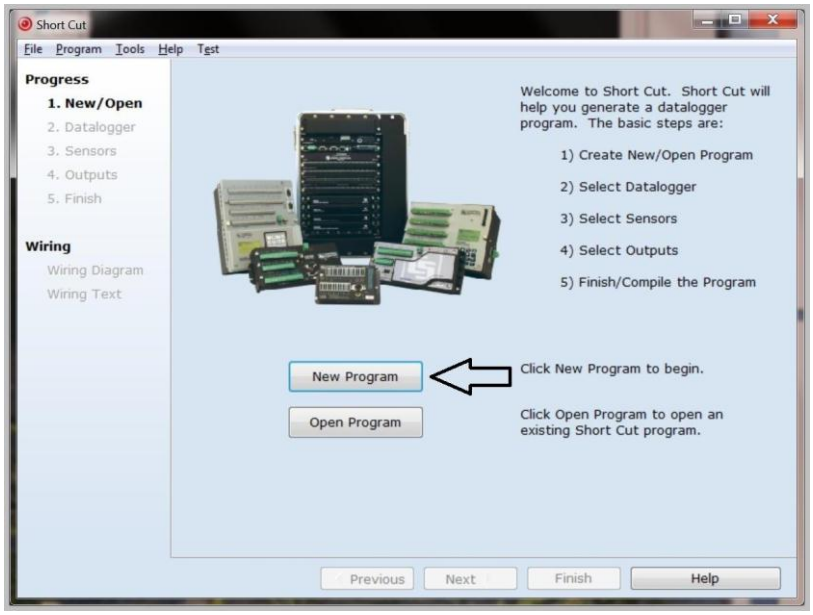
4. Quickstart

Short Cut is an easy way to program your datalogger to measure the LWS and assign datalogger wiring terminals. The following procedure shows using *Short Cut* to program the LWS.

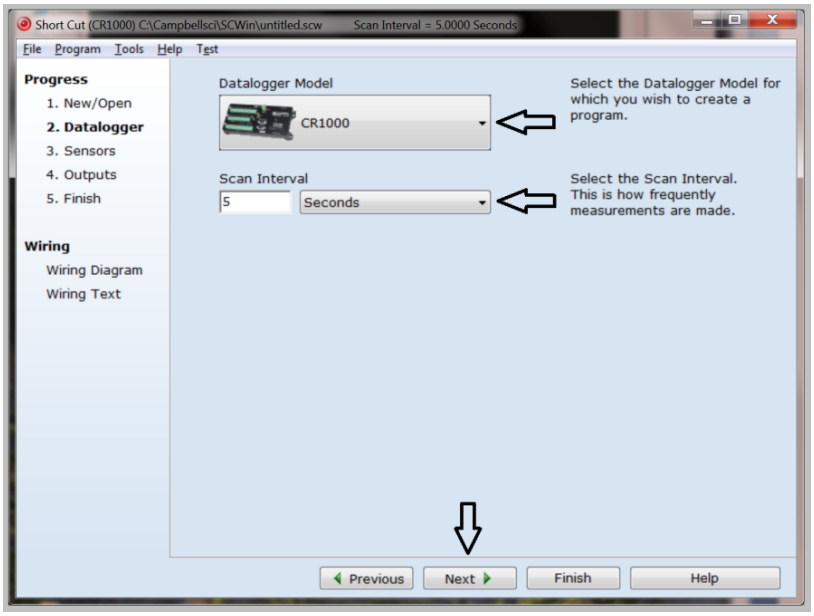
1. Install *Short Cut* by clicking on the install file icon. Get the install file from either *www.campbellsci.com*, the ResourceDVD, or find it in installations of *LoggerNet*, *PC200W*, *PC400*, or *RTDAQ* software.

2. The *Short Cut* installation should place a *Short Cut* icon on the desktop of your computer. To open *Short Cut*, click on this icon.

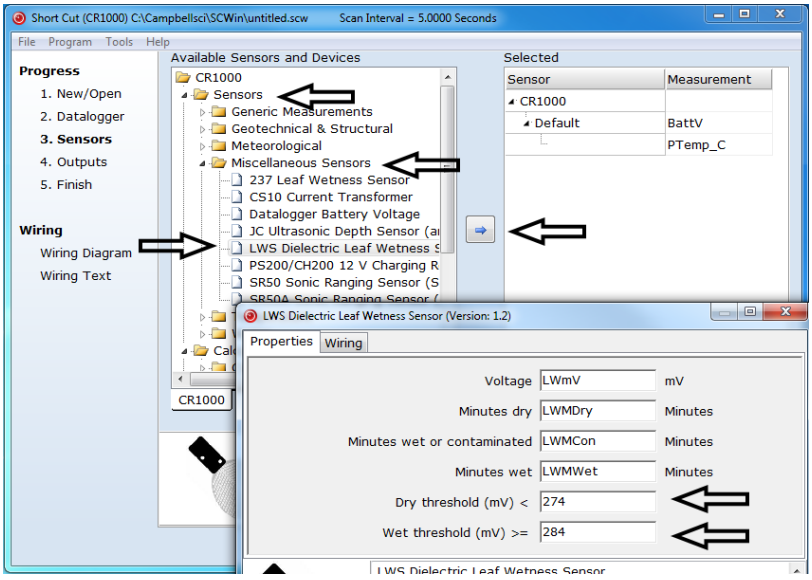
3. When *Short Cut* opens, select **New Program**.



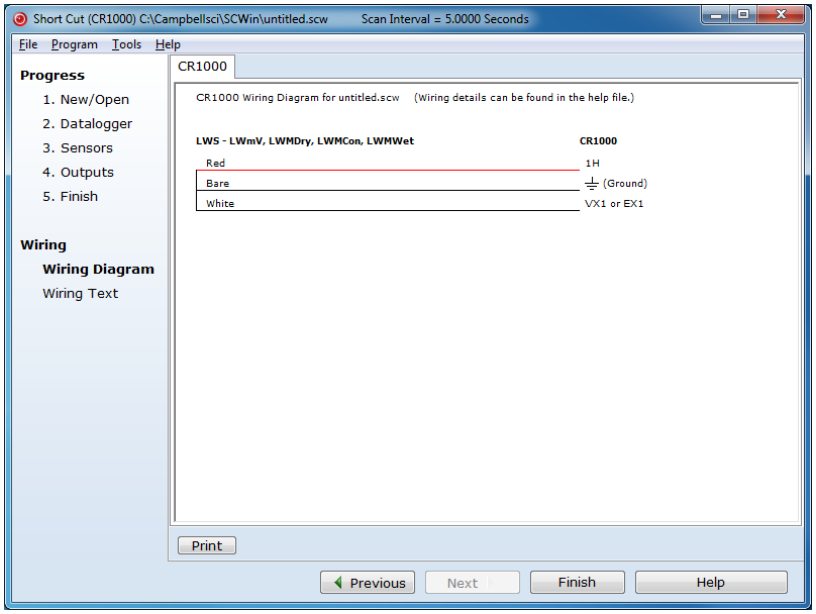
4. Select **Datalogger Model** and **Scan Interval** (default of **5** seconds is OK for most applications). Click **Next**.



5. Under the **Available Sensors and Devices** list, select the **Sensors** | **Miscellaneous Sensors** folder. Select **LWS Dielectric Leaf Wetness Sensor**. Click to move the selection to the **Selected** device window. Enter the **Dry threshold (mV) <** and **Wet threshold (mV) >=** values (see Section 7.3.2, *Interpreting Data* (p. 7), for information about determining the dry threshold and wet threshold values).



6. After selecting the sensor, click at the left of the screen on **Wiring Diagram** to see how the sensor is to be wired to the datalogger. The wiring diagram can be printed out now or after more sensors are added.



7. Select any other sensors you have, then finish the remaining *Short Cut* steps to complete the program. The remaining steps are outlined in *Short Cut Help*, which is accessed by clicking on **Help | Contents | Programming Steps**.

8. If *LoggerNet*, *PC400*, *RTDAQ*, or *PC200W* is running on your PC, and the PC to datalogger connection is active, you can click **Finish** in *Short Cut* and you will be prompted to send the program just created to the datalogger.

9. If the sensor is connected to the datalogger, as shown in the wiring diagram in step 6, check the output of the sensor in the datalogger support software data display to make sure it is making reasonable measurements.

5. Overview

5.1 Measurement

The LWS measures the dielectric constant of a zone approximately 1 cm from the upper surface of the sensor. The dielectric constant of water (≈80) and ice (≈5) are much higher than that of air (≈1), so the measured dielectric constant is strongly dependent on the presence of moisture or frost on the sensor surfaces. The sensor outputs an mV signal proportional to the dielectric of the measurement zone, and therefore proportional to the amount of water or ice on the sensor surface.

5.2 Leaf Mimicry

The LWS is designed to approximate the thermodynamic properties of most leaves. If the specific heat of a typical leaf is estimated at 3750 J kg^{-1} K^{-1}, density estimated at 0.95 g/cm^3, and thickness estimated at 0.4 mm, then the heat capacity of the leaf is ≈1425 J m^{-2} K^{-1}. This heat capacity is closely approximated by the thin (0.65 mm) fiberglass construction of the LWS, which has a heat capacity of 1480 J m^{-2} K^{-1}. By mimicking the thermodynamic properties of a real leaf, the LWS closely matches the wetness state of the canopy.

The sensor closely matches the radiative properties of real leaves. Healthy leaves generally absorb solar radiation in much of the visible portion of the spectrum, but selectively reject much of the energy in the near-infrared. The surface coating of the LWS absorbs well in the near-infrared region, but the white colour reflects most of the visible radiation. Spectroradiometer measurements indicate that the overall radiation balance of the sensor closely matches that of a healthy leaf. During normal use, prolonged exposure to sunlight can cause some yellowing of the coating, which does not affect the probe's function. The surface coating is hydrophobic — similar to a leaf with a hydrophobic cuticle. The sensor should match the wetness state of these types of leaves well, but may not match the wetness duration of pubescent leaves or leaves with less waxy cuticles.

6. Specifications

Features:

- Imitates characteristics of a leaf
- Does not require painting or calibration of individual sensors
- Detects trace amounts of water or ice on the leaf surface
- Compatible with Campbell Scientific CRBasic dataloggers: CR6, CR200(X) series, CR800, CR850, CR1000, CR3000, CR5000, and CR9000(X)

Measurement Time:	10 ms
Excitation:	2.5 Vdc (2 mA) to 5.0 Vdc (7 mA)
Minimum Excitation Time:	10 mS
Output:	10% to 50% of excitation
Operating Temperature:	–20 to 60 °C
Probe Dimensions:	11.2 cm x 5.8 cm x .075 cm
Maximum Lead Length:	76 m (250 ft)
Interchangeability:	Interchangeable without painting or individual calibration

7. Installation

If you are programming your datalogger with *Short Cut*, skip Section 7.2, Wiring *(p. 6)*, and Section 7.3, *Programming (p. 6)*. *Short Cut* does this work for you. See Section 4, *Quickstart (p. 1)*, for a *Short Cut* tutorial.

7.1 Field Installation

The LWS is designed to be mounted on a small diameter rod. Deployment in a plant canopy or on a weather station mast is typical. Two holes in the sensor body are available for mounting with zip ties or 4-40 bolts (Figure 7-1 and Figure 7-2).

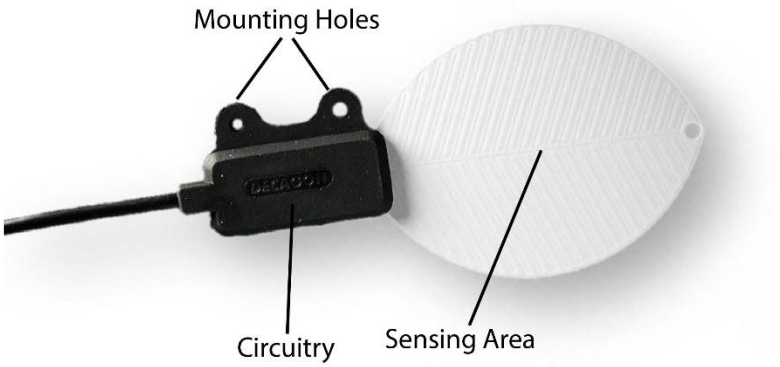


Figure 7-1. LWS Dielectric Leaf Wetness Sensor

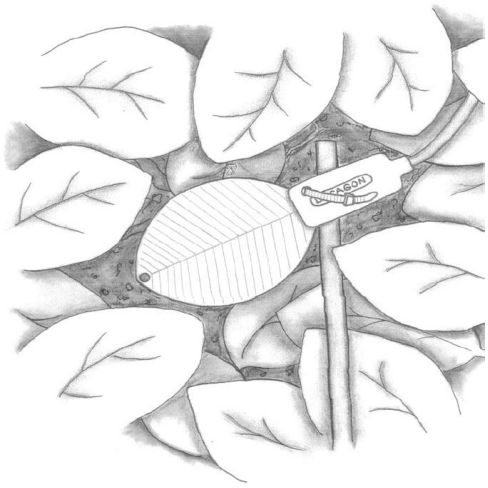


Figure 7-2. Top view of a typical LWS installation

7.2 Wiring

Table 7-1. Wire Colour, Function and Datalogger Connection

Colour	Function	CR200(X), CR6, CR800/850, CR5000, CR3000, CR1000, CR9000(X)
White	Voltage Excitation	Switched Voltage Excitation
Red	Analogue Out	Single-Ended Channel
Bare	Analogue Ground	⏚

7.3 Programming

Short Cut is the best source for up-to-date datalogger programming code. Programming code is needed

- when creating a program for a new datalogger installation
- when adding sensors to an existing datalogger program

If your data acquisition requirements are simple, you can probably create and maintain a datalogger program exclusively with *Short Cut*. If your data acquisition needs are more complex, the files that *Short Cut* creates are a great

source for programming code to start a new program or add to an existing custom program.

NOTE *Short Cut* cannot edit programs after they are imported and edited in *CRBasic Editor*.

A *Short Cut* tutorial is available in Section 4, *Quickstart* *(p. 1)*. If you wish to import *Short Cut* code into *CRBasic Editor* to create or add to a customized program, follow the procedure in Appendix A, *Importing Short Cut Code into a Program Editor* *(p. A-1)*. Programming basics for CRBasic dataloggers are provided in the following sections. A complete program example for a CRBasic datalogger can be found in Appendix B, *Example Programs* *(p. B-1)*. Programming basics and programming examples for Edlog dataloggers are provided at *www.campbellsci.com/old-manuals*.

7.3.1 Voltage Measurement

The LWS requires excitation voltage between 2.5 and 5 Vdc. It produces an output voltage dependent on the dielectric constant of the medium surrounding the probe. Output voltage ranges from 10 to 50% of the excitation voltage.

Except for the CR200(X), CRBasic dataloggers use the **BRHalf()** instruction to measure the probe's output. The **BRHalf()** instruction and parameters are as follows:

BRHalf*(Dest,Reps,Range,SeChan,ExChan,MeasPEx,ExmV,RevEx,Settling,Integ, Mult,Offset)*

The CR200(X) uses the **ExDelSE()** CRBasic instruction to measure the probe's output. The **ExDelSE()** instruction and parameters are as follows:

ExDelSE*(Dest, Reps, SEChan, ExChan, ExmV, Delay, Mult, Offset)*

7.3.2 Interpreting Data

Many leaf wetness applications, such as phytopathology, require a Boolean interpretation of leaf wetness data such as whether or not water is present. A Boolean threshold is determined by analysing a few days of time series data. Consider time series data in Figure 7-3, which were obtained at 5 Vdc excitation. The sensor yields ≈445 mV when dry, ≈475 mV when frosted, and >475 mV when wet. Therefore, a Boolean wetness threshold of 500 mV should serve well for interpreting these data.

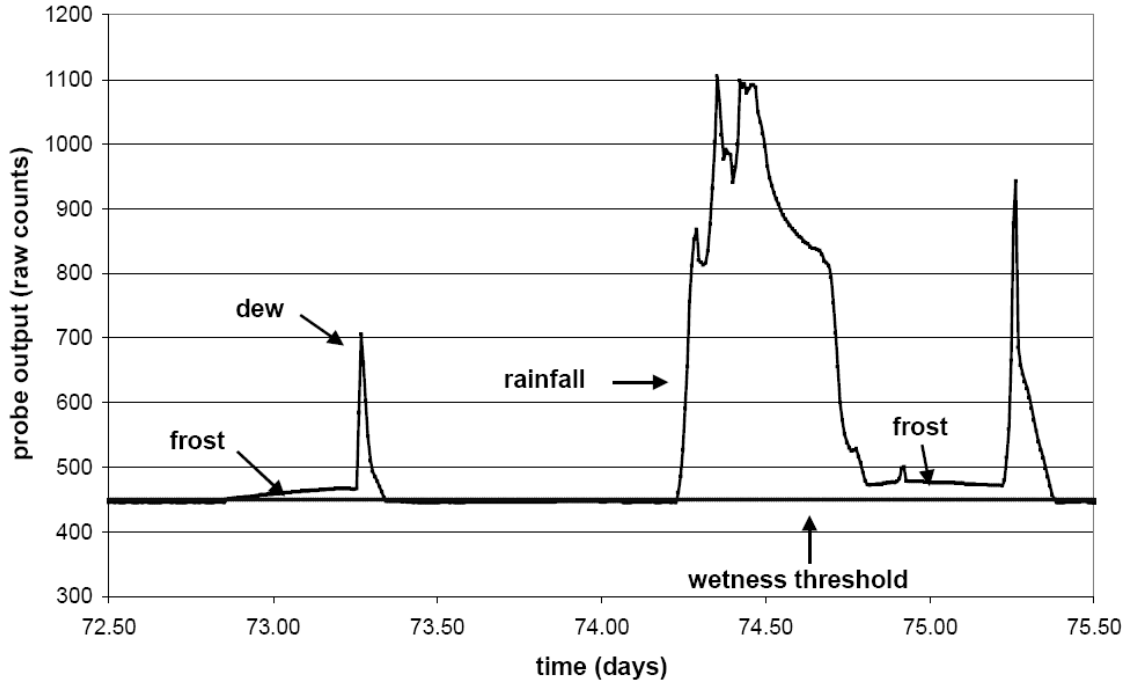


Figure 7-3. Typical LWS response

Duration of leaf wetness can be determined either by post processing of data, or by programming the datalogger to accumulate time of wetness based on the Boolean threshold. Accumulation of dust and debris, such as avian faecal matter, will change the Boolean threshold. So, while having the datalogger accumulate time of leaf wetness, or time of frost, may be convenient, assurance of data quality requires retention of the base mV measurements.

NOTE Collect data frequently enough to capture changes in surface wetness. A sample frequency of 15 minutes or less is usually necessary to accurately capture leaf wetness duration.

8. Maintenance

Over time, the accumulation of dust and debris will cause the dry output to increase and changing the Boolean threshold. Clean the sensing surface with a moist cloth periodically or when elevated dry output is detected.

The LWS leaf wetness sensor is designed to withstand typical outdoor radiation and precipitation loads for greater than two years. If you are using the LWS in areas with non-typical (unusually high) radiation loads, we recommend additional applications of McNett UVTech (available from *www.mcnett.com*) be reapplied every 45 days. McNett is the only tested and approved UV blocking system for this leaf wetness sensor.

To apply McNett UV Tech:

1. Wipe sensor clean.
2. Spray sensor surface with McNett UV Tech.
3. Rub with soft cloth until dry.

9. Acknowledgement

Portions of this manual are copyrighted by Decagon Devices, Inc. and are used by permission.

Appendix A. Importing Short Cut Code into a Program Editor

This tutorial shows:

- How to import a *Short Cut* program into a program editor for additional refinement
- How to import a wiring diagram from *Short Cut* into the comments of a custom program

Short Cut creates files that can be imported into either *CRBasic Editor* or *Edlog* program editor. These files normally reside in the C:\campbellsci\SCWin folder and have the following extensions:

- .DEF (wiring and memory usage information)
- .CR2 (CR200(X) datalogger code)
- .CR6 (CR6 datalogger code)
- .CR1 (CR1000 datalogger code)
- .CR8 (CR800 or CR850 datalogger code)
- .CR3 (CR3000 datalogger code)
- .CR5 (CR5000 datalogger code)

Use the following procedure to import *Short Cut* code into *CRBasic Editor* (CR200(X), CR6, CR1000, CR800, CR850, CR3000, CR5000 dataloggers).

1. Create the *Short Cut* program following the procedure in Section 4, *Quickstart (p. 1)*. Finish the program and exit *Short Cut*. Make note of the file name used when saving the *Short Cut* program.

2. Open *CRBasic Editor*.

3. Click **File** | **Open**. Assuming the default paths were used when *Short Cut* was installed, navigate to C:\CampbellSci\SCWin folder. The file of interest has a ".CR2", ".CR6", ".CR1", ".CR8", ".CR3", or ".CR5" extension, for CR200(X), CR6, CR1000, CR800/CR850, CR3000, or CR5000 dataloggers, respectively. Select the file and click **Open**.

4. Immediately save the file in a folder different from \Campbellsci\SCWin, or save the file with a different file name.

NOTE Once the file is edited with *CRBasic Editor*, *Short Cut* can no longer be used to edit the datalogger program. Change the name of the program file or move it, or *Short Cut* may overwrite it next time it is used.

5. The program can now be edited, saved, and sent to the datalogger.

6. Import wiring information to the program by opening the associated .DEF file. Copy and paste the section beginning with heading "-Wiring for CRXXX–" into the CRBasic program, usually at the head of the file. After pasting, edit the information such that a ' character (single quotation mark) begins each line. This character instructs the datalogger compiler to ignore the line when compiling the datalogger code.

Appendix B. Example Programs

B.1 Example CR1000 Program

The wiring for the example is shown in Table B-1.

Table B-1. CR1000 Example Wiring

Colour	Function	CR1000
White	Excitation	EX1 or VX1
Red	Analogue Out	SE1
Bare	Analogue Ground	⏚

```
'CR1000

'Declare Variables and Units
Public BattV
Public PTemp_C
Public LWmV
Public LWMDry
Public LWMCon
Public LWMWet

Units BattV=Volts
Units PTemp_C=Deg C
Units LWmV=mV
Units LWMDry=Minutes
Units LWMCon=Minutes
Units LWMWet=Minutes

'Define Data Tables
DataTable(Table1,True,-1)
  DataInterval(0,60,Min,10)
  Sample(1,BattV,FP2)
  Sample(1,PTemp_C,FP2)
  Sample(1,LWmV,FP2)
  Totalize(1,LWMDry,FP2,False)
  Totalize(1,LWMCon,FP2,False)
  Totalize(1,LWMWet,FP2,False)
EndTable

DataTable(Table2,True,-1)
  DataInterval(0,1440,Min,10)
  Minimum(1,BattV,FP2,False,False)
EndTable

'Main Program
BeginProg
  'Main Scan
  Scan(5,Sec,1,0)
    'Default Datalogger Battery Voltage measurement 'BattV'
    Battery(BattV)
    'Default Wiring Panel Temperature measurement 'PTemp_C'
    PanelTemp(PTemp_C,_60Hz)

    'LWS Dielectric Leaf Wetness Sensor measurement 'LWmV'
     BrHalf(LWmV,1,mV2500,1,1,1,2500,False,10000,_60Hz,2500,0)

    'Determine Minutes Dry, LWMDry, Minutes Wet or Contaminated, ‘LWMCon, and Minutes Wet,
LWMWet for this Scan
    LWMDry=0
    LWMCon=0
    LWMWet=0
```

```
    If LWmV<274 Then
      LWMDry=0.08333333
    Else
      If LWmV>=284 Then
        LWMWet=0.08333333
      Else
        LWMCon=0.08333333
      EndIf
    EndIf
    'Call Data Tables and Store Data
    CallTable(Table1)
    CallTable(Table2)
  NextScan
EndProg
```

B.2 Example CR6 Program

The wiring for the example is shown in Table B-2.

Table B-2. CR6 Example Wiring

Colour	Function	CR6
White	Excitation	U1
Red	Analogue Out	U2
Bare	Analogue Ground	⏚

```
'CR6 Series

'Declare Variables and Units
Public BattV
Public PTemp_C
Public LWmV
Public LWMDry
Public LWMCon
Public LWMWet

Units BattV=Volts
Units PTemp_C=Deg C
Units LWmV=mV
Units LWMDry=Minutes
Units LWMCon=Minutes
Units LWMWet=Minutes

'Define Data Tables
DataTable(Table1,True,-1)
  DataInterval(0,60,Min,10)
  Sample(1,LWmV,FP2)
  Totalize(1,LWMDry,FP2,False)
  Totalize(1,LWMCon,FP2,False)
  Totalize(1,LWMWet,FP2,False)
EndTable
```

```
DataTable(Table2,True,-1)
  DataInterval(0,1440,Min,10)
  Minimum(1,BattV,FP2,False,False)
EndTable

'Main Program
BeginProg
  'Main Scan
  Scan(5,Sec,1,0)
    'Default Datalogger Battery Voltage measurement 'BattV'
    Battery(BattV)

    'Default Wiring Panel Temperature measurement 'PTemp_C'
    PanelTemp(PTemp_C,60)

    'LWS Dielectric Leaf Wetness Sensor measurement 'LWmV'
    BrHalf(LWmV,1,mV5000,U2,U1,1,2500,False,10000,60,2500,0)

    'Determine Minutes Dry 'LWMDry', Minutes Wet or Contaminated
    'LWMCon', and Minutes Wet 'LWMWet' for this Scan
    LWMDry=0
    LWMCon=0
    LWMWet=0
    If LWmV<274 Then
      LWMDry=0.08333333
    Else
      If LWmV>=284 Then
        LWMWet=0.08333333
      Else
        LWMCon=0.08333333
      EndIf
    EndIf

    'Call Data Tables and Store Data
    CallTable Table1
    CallTable Table2
  NextScan
EndProg
```

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